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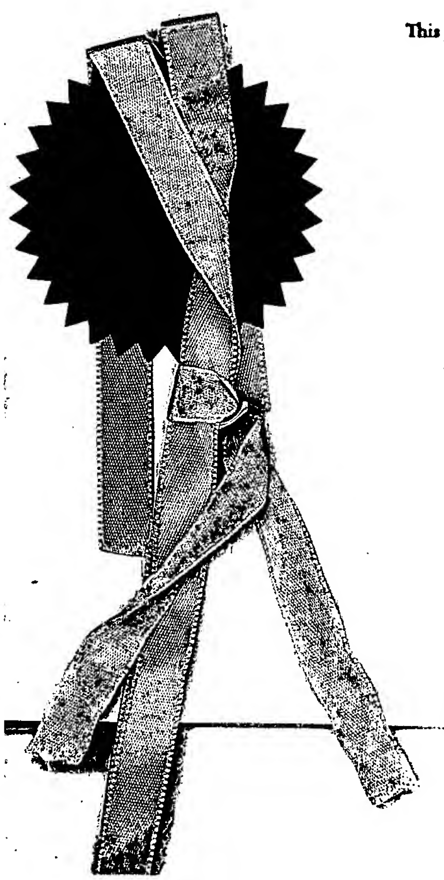

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מספר: Number	108352
תאריך: Date	17-01-1994
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חוק הפטנטים, תשכ"ז – 1967
PATENT LAW, 5727 - 1967

בקשה לפטנט
Application for Patent

אני, (שם המבקש, מענו ולגבי גוף מאוגד - מקום התאגדותו)
I (Name and address of applicant, and in case of body corporate-place of incorporation)

מדינת ישראל/משרד הביטחון
רשות פיתוח אמצעי לחימה – רפאל
ת.ד. 2250
חיפה 31021

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בעל אמצאה מכח החוק ששמה הוא
Owner, by virtue of the law of an invention the title of which is

(בעברית) (Hebrew) מערכת צילום תוך גופית

(באנגלית) (English) AN IN VIVO VIDEO CAMERA SYSTEM

מבקש בזאת כי ינתן לי עליה פטנט
hereby apply for a patent to be granted to me in respect thereof.

• בקשת חלוקה — Application of Division	• בקשת פטנט מוסף — Application for Patent Addition	• דרישה דין קדימה Priority Claim		
מבקשת פטנט from Application	• לבקשה/לפטנט to Patent/Appl.	מספר/סימן Number/Mark	תאריך Date	מדינת האגוד Convention Country
No. .... מס'	No. .... מס'			
dated .... מיום	dated .... מיום			

• ייפוי כח: [redacted] / עוד יוגש
P.O.A.: general/individual-attached/to be filed later-
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היום 16 בחודש 1 שנת 1994
This 16 of 1 of the year 1994

חתימת המבקש
Signature of Applicant
עבור המבקש
הידידי מ. ברוך עו"ס
משרד עורכי דין, טלי א. איתן

P-IO-528-IL

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AN IN VIVO VIDEO CAMERA SYSTEM

מערכת צילום תוך גופית

A. Tally Eitan Law Offices
C:P-IO-528-IL

FIELD OF THE INVENTION

The present invention relates to in vivo measurement systems such as for the digestive system in general and in vivo video camera systems in particular.

BACKGROUND OF THE INVENTION

Various in vivo measurement systems are known in the art. They typically include swallowable electronic capsules which collect data and which transmit the data to a receiver system. These intestinal capsules, which are moved through the digestive system through the action of digestion, are often called "Heidelberg" capsules and are utilized to measure pH, temperature and pressure throughout the intestines. They have also been utilized to measure gastric residence time, which is the time it takes for food to pass through the stomach and intestines.

The intestinal capsules typically include a measuring system and a transmission system, where the transmission system transmits the measured data at radio frequencies to the receiver system.

The following articles describe swallowable electronic capsules:

E.N. Rowland and H.S. Wolff, "The Radio Pill: Telemetering from the Digestive Tract", British Communications and Electronics, August 1960, pp. 598 – 601; and

Yarborough, D.R. III, et al., "Evaluation of the Heidelberg Capsule: Method of Tubeless Gastric Analysis", The American Journal of Surgery, Vol. 117, February 1969, pp. 185 – 191.

Other in vivo measuring systems are endoscopes, long tubes which the patient swallows. These are often utilized to

provide images of the upper or lower gastro-intestinal tract. However, because they are not very flexible, they do not move easily through small intestines, and thus, they do not provide views of the small intestines.

There are currently two types of endoscopes. Fiber-optic endoscopes utilize a fiber optic waveguide to transmit the video signal from the area of interest to the electronics located outside the patient's body. Video endoscopes place an electronic camera at the area of interest and store the images until after the test finishes.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide a tubeless in vivo video camera system. Such a system includes a capsule which can pass through the entire digestive tract and thus, operates as an autonomous video endoscope.

There is therefore provided, in accordance with a preferred embodiment of the present invention, an in vivo video camera system including a swallowable capsule and a reception system. The capsule includes a) a camera system, b) an optical system for imaging an area of interest onto the camera system and c) a transmitter which transmits the video output of the camera system.

Additionally, in accordance with a preferred embodiment of the present invention, the reception system receives the transmitted video output and includes a) an antenna array capable of surrounding a body for receiving the transmitted video output and for producing a plurality of received signals and b) a demodulator capable of transforming the plurality of received video signals into a single video datastream.

Moreover, in accordance with a preferred embodiment of the present invention, the system includes a data processing system which generates tracking and video data from the single datastream. Optionally, the system can also include apparatus for operating the transmitter intermittently.

Finally, in accordance with a preferred embodiment of the present invention, the optical system includes a viewing window located along one side of the swallowable capsule.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Fig. 1 is a block diagram illustration of an in vivo video camera system, constructed and operative in accordance with a first preferred embodiment of the present invention;

Fig. 2 is a schematic illustration of a video camera capsule forming part of the system of Fig. 1;

Fig. 3A is a schematic illustration of a transmitter forming part of the capsule of Fig. 2;

Fig. 3B is a circuit diagram illustration of the transmitter of Fig. 3A;

Fig. 4 is a pictorial illustration of a portable reception system forming part of the system of Fig. 1;

Fig. 5 is a schematic illustration of a reception system forming part of the system of Fig. 1;

Fig. 6 is a pictorial illustration of an alternative embodiment of the present invention having a stationary reception system;

Figs. 7 and 8 are schematic illustration of calculations performed by a data processor, wherein Fig. 6 is a top view illustration of the antenna array and Fig. 7 is a cross-sectional illustration of the antenna array.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now briefly made to Fig. 1 which illustrates, in block diagram format, an in vivo video camera system, constructed and operative in accordance with preferred embodiments of the present invention.

The in vivo video camera system typically comprises a swallowable capsule 10 for viewing inside the digestive system and for transmitting at least video data, a reception system 12 typically located outside a patient, and a data processor 14 for processing the video data. The data processor 14 typically operates two monitors, a position monitor 16 on which the current location of the capsule 10 within the digestive system is displayed and an image monitor 18 on which the image currently viewed by the capsule 10 is displayed.

The reception system 12 can either be portable, in which case, the data it receives is temporarily stored in a storage unit 19 prior to its processing in data processor 14, or it can be stationary and close to the data processor 14.

Reference is now made to Figs. 2, 3A and 3B which illustrate the capsule and its elements. The capsule 10 typically comprises a light source 20 (Fig. 2), a viewing window 22 through which the light illuminates the inner portions of the digestive system, a camera system 24, such as a charge-coupled device (CCD) camera, which detects the images, an optical system 26 which focusses the images onto the CCD camera system 24, a transmitter 28 which transmits the video signal of the CCD camera system 24 and a power source 29, such as a battery, which provides power to the entirety of electrical elements of the capsule.

The capsule can additionally include sensor elements for measuring pH, temperature, pressure, etc. These sensor elements are described in the prior art.

A suitable small CCD camera system 24 is the ASIS-1011-B single chip camera manufactured by VLSI Vision Ltd. of Birmingham, Scotland. This single chip includes the CCD device and the

electronics for producing a video signal from the output of the CCD device. The CCD device can either provide black and white signals or color signals.

Because it is desired to view the walls of the digestive tract, the viewing window 22 typically is located on a side 23 of the capsule 10. Accordingly, the optical system 26 typically comprises a mirror 27 and a focussing lens 29. The mirror 27 is a dichroic mirror which transmits the light from the light source 20, such as a light emitting diode, to the walls of the digestive tract via the viewing window 22. Mirror 27 also deflects the light reflected from the digestive system towards the lens 29. Lens 29 then focusses the light onto the CCD camera system 24.

A suitable transmitter 28 is illustrated in Fig. 3A. It comprises a modulator 30 receiving the video signal from the CCD camera 24, a radio frequency (RF) amplifier 32, an impedance matcher 34 and an antenna 36. The modulator 30 converts the input video signal having a cutoff frequency f_c of less than 5 MHz to an RF signal having a carrier frequency f_r, typically in the range of 1 GHz. After amplification by amplifier 32, the RF signal has a bandwidth of f_c. The impedance matcher 34 increases the impedance of the circuit to match that of the antenna 36.

Fig. 3B illustrates one possible implementation of the transmitter 28 producing less than 1 milliwatt of power. It comprises two coupled oscillator tanks 31 and 33, each formed of an inductor and a capacitor, wherein oscillator tank 33 includes a variable capacitor 35. Additionally, the transmitter 28 comprises a voltage divider 37, a transistor 39 and an impedance matching capacitor 41.

The two oscillator tanks 31 are connected in a regeneration loop via transistor 39. The voltage divider 37 typically divides the input voltage, typically of 3V.

It is noted that the capsule is moved through the digestive tract via the peristaltic motion of the digestive muscles. Since the focal plane of the optical system 26 is fixed

close to the housing of the capsule 10, only body parts located close by can be viewed. Thus, the capsule is typically effective only within the small and large intestines.

For example, in the small intestines, the muscles squeeze only when food (or the capsule 10) passes them by. The capsule 10 can optionally be designed to collect images only when the muscles are squeezing. This saves battery power, but requires either a sensor, such as a pressure sensor, or a duty cycle based on the expected operation of the muscles.

Reference is now made to Figs. 4 and 5 which illustrate a portable embodiment of the reception system 12. The reception system 12 typically comprises an antenna array 40, wrapped around the central portion of a trunk 41 of the patient, and a signal sampler 42.

The antenna array 40 typically comprises a multiplicity of antennas 44, each formed of a rectangular or circular coil of wire, held within a suitably insulating material, such as cloth or plastic. In the exemplary embodiment illustrated in Fig. 4, there are shown 16 antennas 42, formed into two rows of eight antennas 42 each. Fewer or more antennas can be utilized as long as they are located so as to be able to determine from their output the location of the capsule 10 within the body of the patient.

The signal sampler 42 typically comprises a multiplicity of receivers 46 (Fig. 3), one for each antenna 44 and connected thereto with a thin coaxial cable 47, and a multiplexer 48. The receivers 46 decipher the data provided by their corresponding antennas 44. The multiplexer 48 continually scans the output of the receivers 46, providing the combined antenna data as a single output signal.

A suitable receiver 46 must be capable of detecting a signal having the carrier frequency f_r and the bandwidth f_c described hereinabove. Such a receiver can be similar to those found in televisions or it can be one similar to those described on pages 244 - 245 of the book <u>Biomedical Telemetry</u> by R. Stewart

McKay and published by John Wiley and Sons, 1970.

As the capsule 10 moves through the digestive system, it views walls of the digestive system and transmits the resultant images to the reception system 12. The reception system 12 receives a multiplicity of versions of the images, each version received by a different antenna 44, and either stores the received signals in the storage unit 19 or provides the received signals to the data processor 14.

From the multiplicity of versions of the images, the position of the capsule 10 within the trunk 41 can be determined and the signal from the antenna 44 closest to the capsule 10 at any given time chosen as the current video source.

Reference is now made to Fig. 6 which illustrates a stationary in vivo video camera system. In this alternative embodiment, the antenna array 40 and sampler 42 are affixed to a table 50 on which a patient 52 lies. As in the previous embodiment, the antenna array 40 surrounds the central portion of the patient's trunk 41.

In this alternative embodiment, the output of sampler 42 is provided directly to data processor 14 which then outputs its results on position monitor 16 and image monitor 18, wherein the position monitor 16 typically displays the present and past locations of the capsule 10 within the digestive system and the image monitor 18 typically displays the image viewed by the capsule 10 when at the final location marked on position monitor 16. The output of the data processor 14, as well as of the reception system 12, can also be stored in storage unit 19.

The operation of processing unit 14 will now be described with reference to Figs. 7 and 8.

The data processor 14 determines the image to be provided on image monitor 18 by continually determining which antenna 44 provides the strongest signal. To do so, the data processor 14 first separates the signal from the reception system 12 into the components from each antenna 44, determines the amount of power in the signals of each antenna 44 and then selects the one with the

highest power.

To determine the location of the capsule 10, the data processor 14 first separates the signal from the reception system 12 into the components from each antenna 44. It then determines the location of the capsule 10 by comparing the output of certain ones of the antennas 44.

Fig. 7 is a front view illustration of the patient 52 with the antenna array 40 wrapped around him. On it four antennas 44a - 44d are noted. Antennas 44a and 44b are located in a column at one side of the patient 52 and antennas 44c and 44d are located in a column at the other side of the patient 52.

Since the strength of a signal received by any given antenna depends on its distance from and angle to the transmitter, the ratio of the signal strengths between any two antennas which have the transmitter between them is constant along a curve which intersects the location of the transmitter. Thus, antennas 44a and 44b define curve 60a and antennas 44c and 44d define curve 60b.

The intersection of curves 60a and 60b is the location of the transmitter which is the location of the capsule 10. The curves 60a and 60b are typically determined in a calibration step for a predefined number of constant values.

The designation of antennas 44a - 44d depends on and is determined from the width L_1 of the patient 52, which value is typically provided to data processor 14. Alternatively, there can be a plurality of antenna arrays 40, one for each of a pre-defined number of widths L_1. The antennas 44a - 44d are then constant for each antenna array 40.

The location of the capsule 10 thus generated is typically denoted by a two-dimensional vector **P**, having a length P and an angle Θ, from the center point O of an X-Y coordinate system.

The cross-sectional location (within an X-Z plane) of the capsule 10 can also be determined using a similar calculation to that illustrated in Fig. 7. A cross-section of the patient 52 is

illustrated in Fig. 8. For this determination, four antennas 44e – 44h, which are opposite in a cross-sectional manner, are utilized.

Once again, the ratio of the signal strengths between two antennas which have the transmitter between them is constant along a curve which intersects the location of the transmitter. Thus, antennas 44e and 44h define curve 60c and antennas 44f and 44g define curve 60d.

The location of the capsule 10 thus generated is typically denoted by a two-dimensional vector **Q** having a length Q and an angle ϕ, from the center point O.

The two vectors **P** and **Q** are combined to determine the three-dimensional location of the capsule 10. The location can be displayed two- or three-dimensionally on position monitor 16, typically, though not necessarily, as an overlay to a drawing of the digestive tract.

It will be appreciated that other methods of determining the location of the capsule 10 can alternatively be utilized, as can other reception systems.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow:

CLAIMS

1. An in vivo video camera system comprising:

a swallowable capsule comprising:

a camera system;

an optical system for imaging an area of interest onto said camera system; and

a transmitter which transmits the video output of said camera system; and

a reception system which receives said transmitted video output.

2. A system according to claim 1 and wherein said reception system comprises:

an antenna array capable of surrounding a body and comprising a plurality of antennas for receiving said transmitted video output and for producing a plurality of received signals; and

a demodulator capable of transforming said plurality of received video signals into a single video datastream.

3. A system according to claim 2 and also comprising a data processing system which generates tracking and video data from said single datastream.

4. A system according to any of the previous claims and including means for operating said transmitter intermittently.

5. A system according to any of the previous claims and wherein said optical system includes a viewing window located along one side of said swallowable capsule.

6. A reception system operable with a swallowable transmitting capsule, the reception system comprising:

an antenna array capable of surrounding a body and comprising a plurality of antennas for receiving transmitted video

output from said capsule and for producing a plurality of received video signals; and

a demodulator capable of transforming said plurality of received video signals into a single video datastream.

7. An autonomous video endoscope comprising:

a swallowable capsule comprising:

a camera system;

an optical system for imaging an area of interest onto said camera system; and

a transmitter which transmits the video output of said camera system; and

a reception system which receives said transmitted video output.

8. A system according to claim 7 and wherein said reception system comprises:

an antenna array capable of surrounding a body and comprising a plurality of antennas for receiving said transmitted video output and for producing a plurality of received signals; and

a demodulator capable of transforming said plurality of received video signals into a single datastream.

9. A system according to claim 8 and also comprising a data processing system which generates tracking and video data from said single datastream.

10. Apparatus substantially as shown and described hereinabove.

11. Apparatus substantially as illustrated in any of the drawings.

For the Applicant,

Heidi M. Brun

Heidi M. Brun, P.A.
Law Offices of A. Tally Eitan
C:P-IO-528-IL

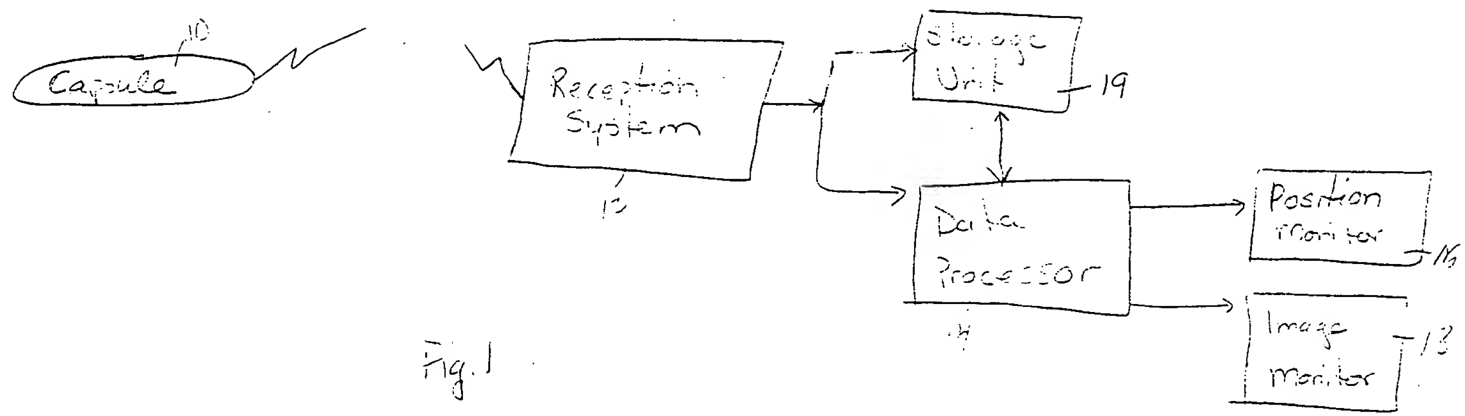

10
Capsule
Reception System
12
Storage Unit
19
Data Processor
14
Position monitor
16
Image monitor
18

Fig. 1

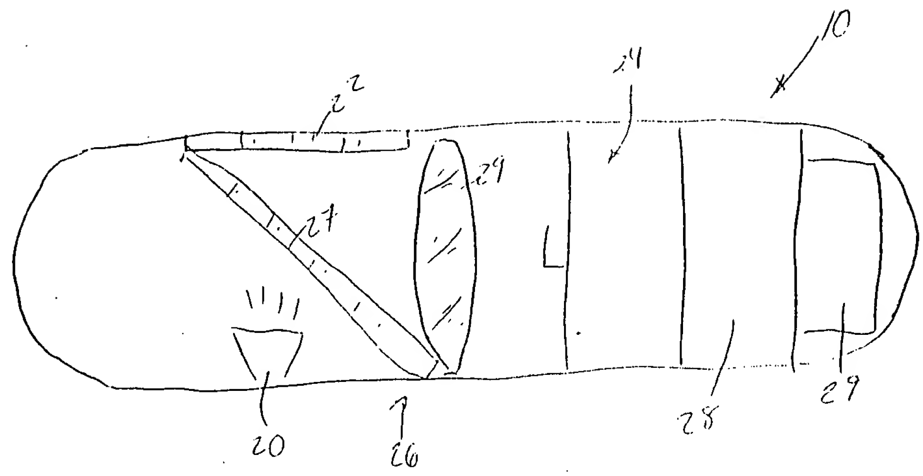


Fig. 2

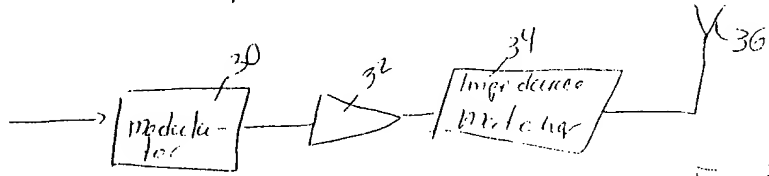


Fig. 3A

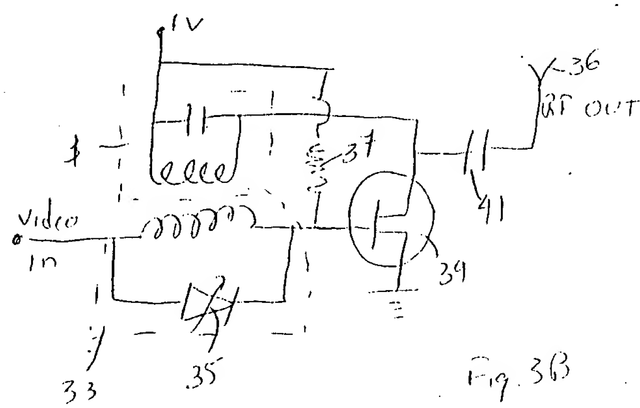
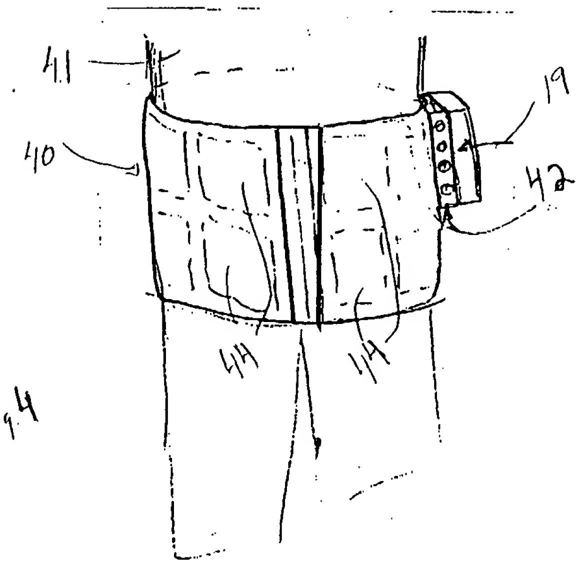


Fig. 3B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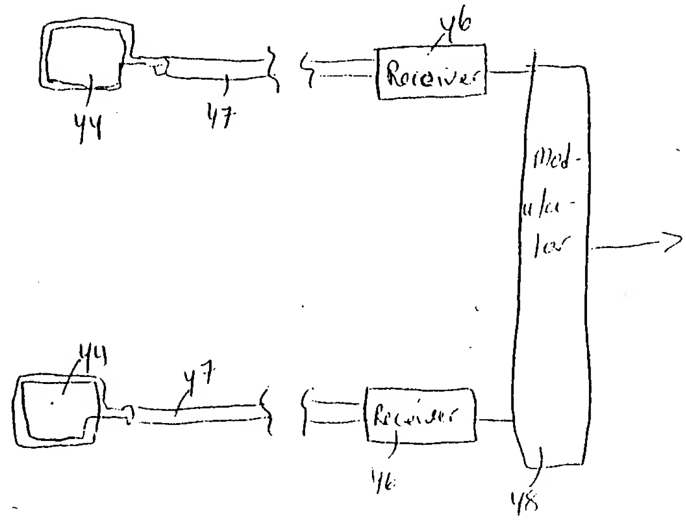
19
40
42
44
44

Fig. 4


46
Receiver
44
47
Mod-
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44
47
Receiver
46
48

Fig. 5

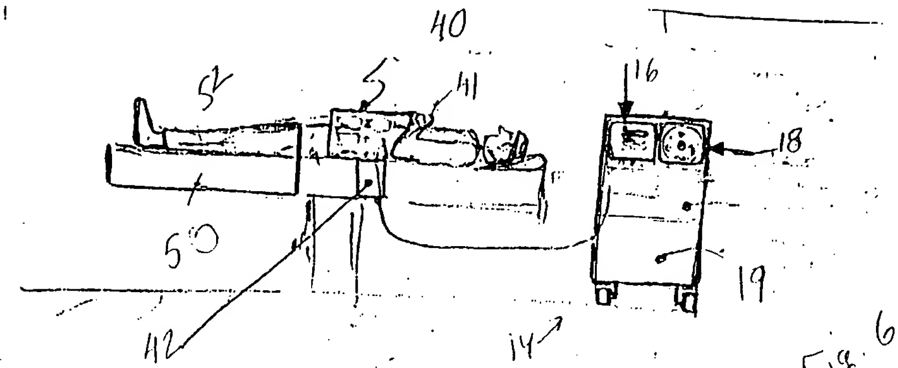

Fig. 6

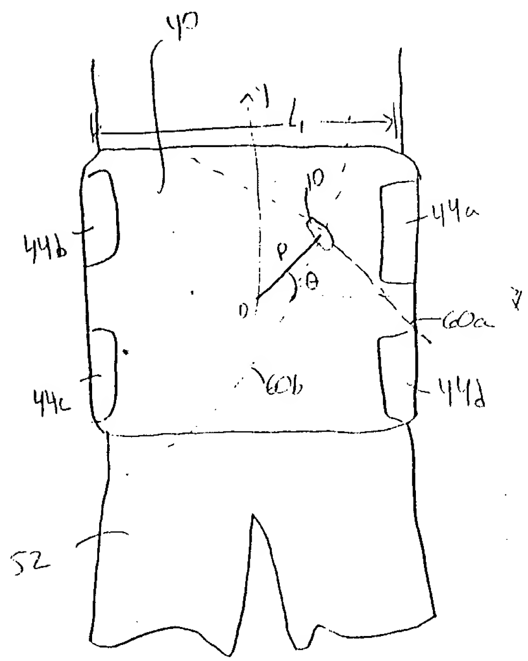

Fig. 7

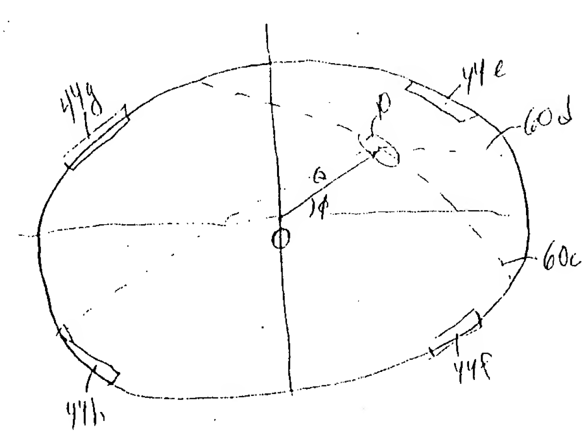

Fig. 8